



14.4 - ENGINE CONTROLS

14.4.1. GENERAL

Just a few words to reassure those of you who have not yet studied all the engine's operational features (especially the governing system) at the engine manufacturer's. Don't worry if you do not completely grasp all the details of how the engine controls act. Everything will become much clearer once you have studied the engine; you will then be able to reread - and fully understand - this chapter.

The engine controls determine the quantity of fuel injected into the combustion chamber in the various operating configurations:

STARTING - FLIGHT - ENGINE SHUTDOWN

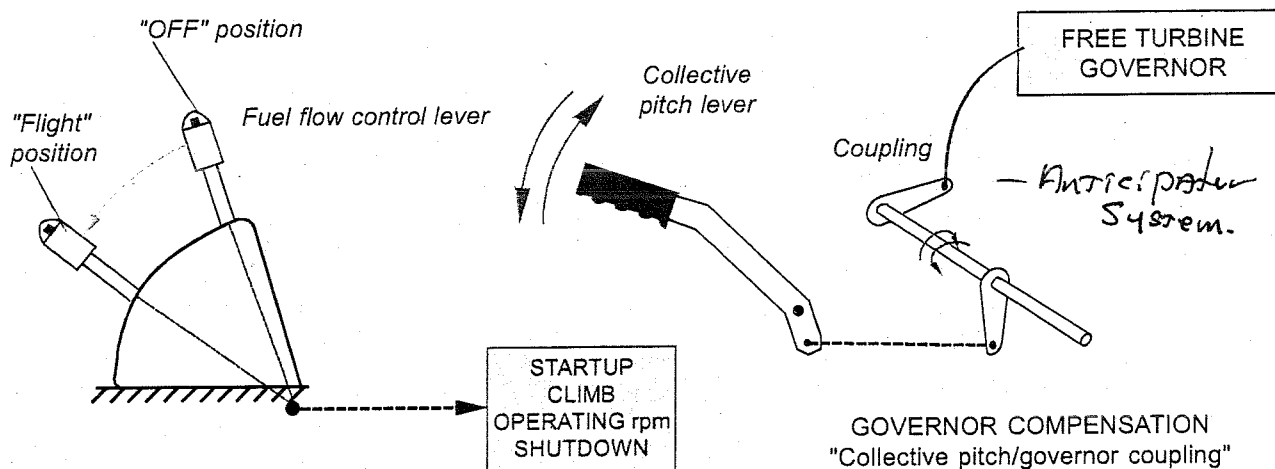
The engine has 2 mechanical controls:

- A fuel flow control operated by the pilot (fuel flow control lever),
- An automatic engine governor compensation control, coupled to the collective pitch control.

This means the pilot has only one direct control to operate, i.e. the fuel flow control lever which, moreover, is only used for engine starting, shutdown and acceleration to the governed rpm (flight position).

Thus when the fuel flow control lever is in "flight" position, the pilot has nothing to do (except to fly the helicopter) since the engine is controlled by its governing system, which automatically meters the fuel quantity to match the power demand (collective pitch function) and which, at the same time, keeps the free turbine rpm constant. The governing control acts on the free turbine governor; the control reacts automatically to collective pitch variations and:

- it compensates for the STATIC DROOP of the centrifugal governor, by maintaining a **CONSTANT** rotor rpm (NR) irrespective of the fuel flow and hence irrespective of the power demand.
- it has a very fast **RESPONSE TIME** to prevent surging during sudden accelerations and flameout during sudden decelerations. This is why this control is also called an **ANTICIPATOR** since it acts prior to the normal reaction of the centrifugal governor.



WHAT IS STATIC DROOP?

The function of the free turbine governor is to maintain the free turbine speed (and hence the rotor speed as well) constant. The governor is a simple WATT type, consisting of a directly acting, flyweight centrifugal governor operating in an "open loop".

In other words, the governor transmits a control order (it detects rpm variations and counteracts them) but it does not check or correct the results of its action. It cannot operate "intelligently" because it is not informed of the effects of its action. In cybernetics, such a governing

system is termed "open loop", as opposed to "closed loop" systems where there is a feedback from the sensing element which compares the result with a reference value and modifies its magnitude. Consequently, with such a governor, the rotor rpm is not strictly constant: compared to the selected governor speed, the rpm drops slightly when the power demand increases and rises slightly when the power demand decreases. This small rpm difference is called "static droop".

Let's now take a closer look...



14.4.1. GENERAL (Cont'd)

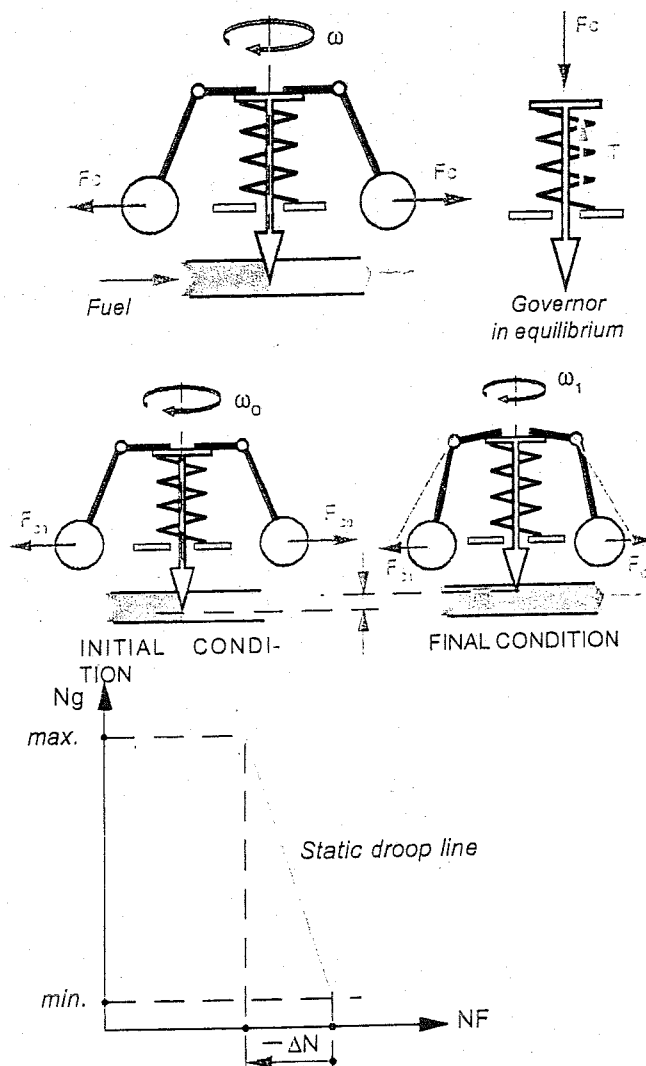
WHAT IS STATIC DROOP? (CONT'D)

The operation of a free turbine governor is illustrated in the diagrams on this page.

The free turbine drives the flyweights, which are subjected to a centrifugal force F_c varying with the free turbine rpm ω ($F_c = M \omega^2 R$). At a given rpm, the centrifugal force is balanced by the tension T of the spring. Any given position of the fuel metering unit corresponds to one - and only one - position of the flyweights (which depends on ω).

N.B. In reality, the flyweights do not act directly on the metering unit but this in no way affects the principle of operation.

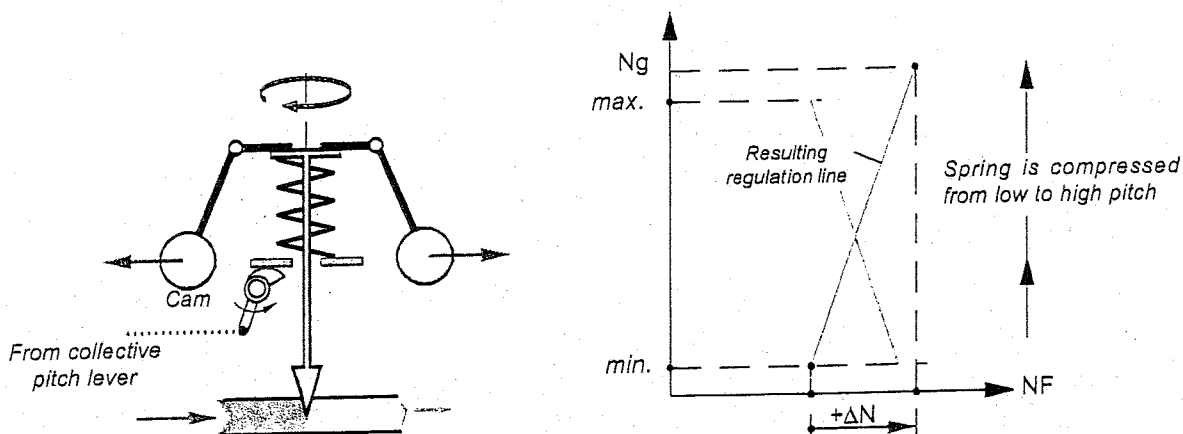
If, at a stabilized rpm ω_0 , the rotor rpm decreases (i.e. an increase in pitch), the centrifugal force decreases and the spring then moves the flyweights closer in to each other. The metering unit increases the fuel flow area, which increases the engine power and hence the rotor rpm. When the increasing engine power equals the power demand, the rotor rpm stabilizes, the governor is in a new equilibrium position but the metering unit is slightly open and the equilibrium rpm ω_1 is slightly below the initial stabilized rpm ω_0 due to the reduction in spring tension. Conversely with a decrease in pitch, the metering unit closes to generate a stabilized rpm slightly above the initial speed. The value of static droop therefore depends directly on the tension of the spring in its travel: a "hard" spring produces a smaller ΔN than a "soft" spring.



COMPENSATING FOR STATIC DROOP AND DECREASING THE RESPONSE TIME

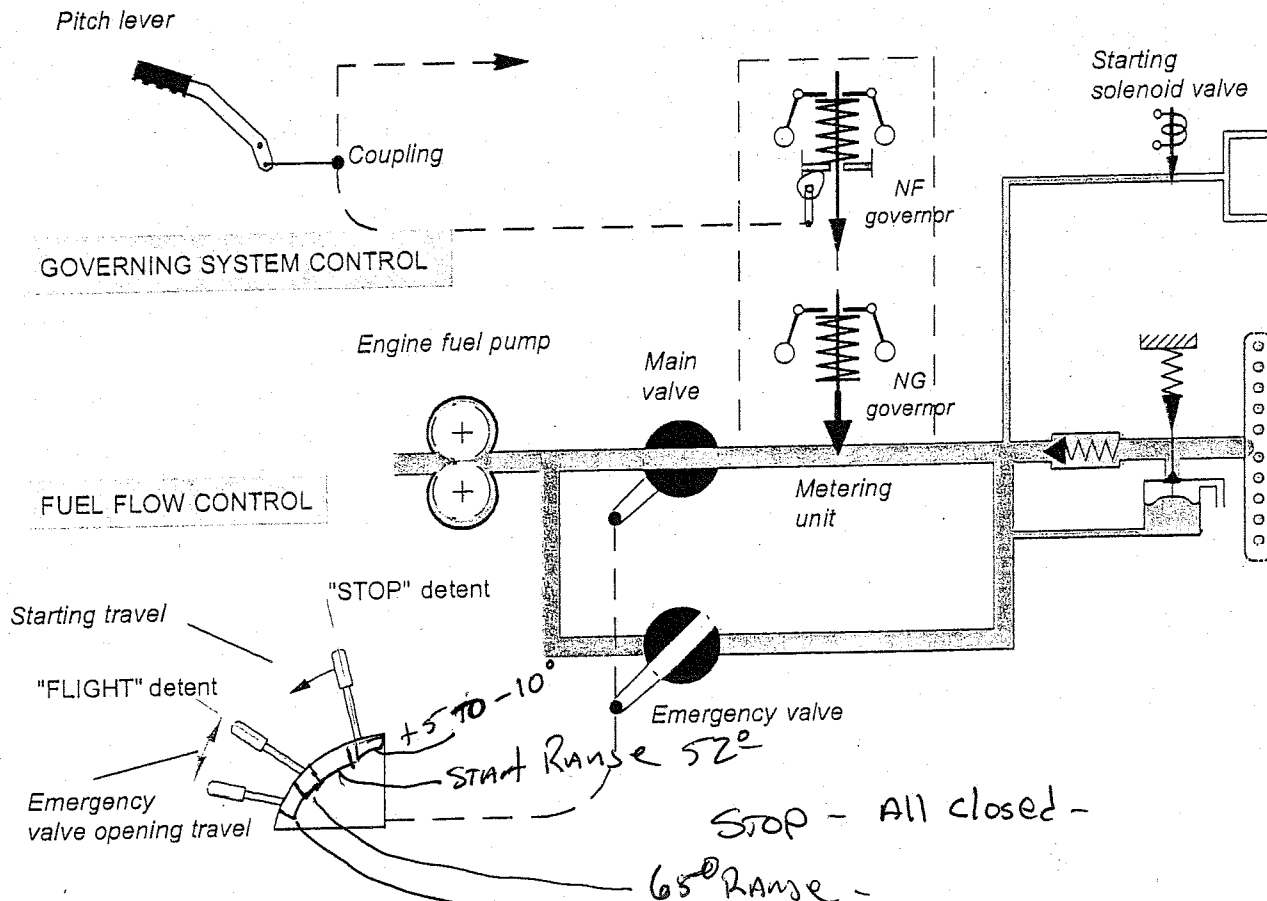
The idea is therefore to harden the spring as the pitch increases, i.e. "pitch/governor" coupling. This produces a resulting regulation line whose slope is reversed relative to the static droop line, which slightly increases NF

(+ ΔN) when the pitch increases. Moreover, the direct action of the pitch control on the governor reduces its response time during collective pitch changes.





14.4.2. OPERATING PRINCIPLE OF ENGINE CONTROLS



THE FUEL FLOW CONTROL LEVER operates 2 flow control valves. In the first part of its travel (from the "STOP" detent to the "FLIGHT" detent), the lever progressively opens the main flow control valve. In the second part of its travel beyond the "FLIGHT" detent, it progressively opens the emergency control valve. To move the lever out of its "FLIGHT" detent and into the "EMERGENCY" sector, the pilot must release the fuel flow control lever.

. With the fuel flow control lever fully back, both valves are closed: this is the engine shutdown (STOP) position.

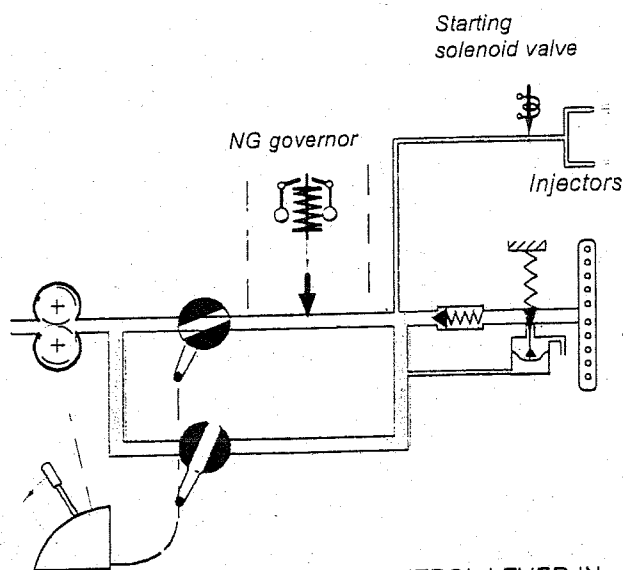
. With the fuel flow control lever in the "starting" range:

- the main valve is partly open.
- the metering unit opening is determined by the fuel control lever position and by the acceleration control unit (refer to engine manufacturer's documentation).

At the same time (these functions are independent of the fuel flow control lever):

- the starting solenoid valve is open (the pilot operates the electric starting control).
- the bleed valve is closed (this function is controlled by the fuel pressure).

The fuel flow delivered to the injectors is adjusted by the pilot, who opens the flow valve more or less to ensure the T4 temperature limit (gas temperature at free turbine inlet) is not exceeded during engine start-up.



FUEL FLOW CONTROL LEVER IN STARTING RANGE



14.4.2. OPERATING PRINCIPLE OF ENGINE CONTROLS (Cont'd)

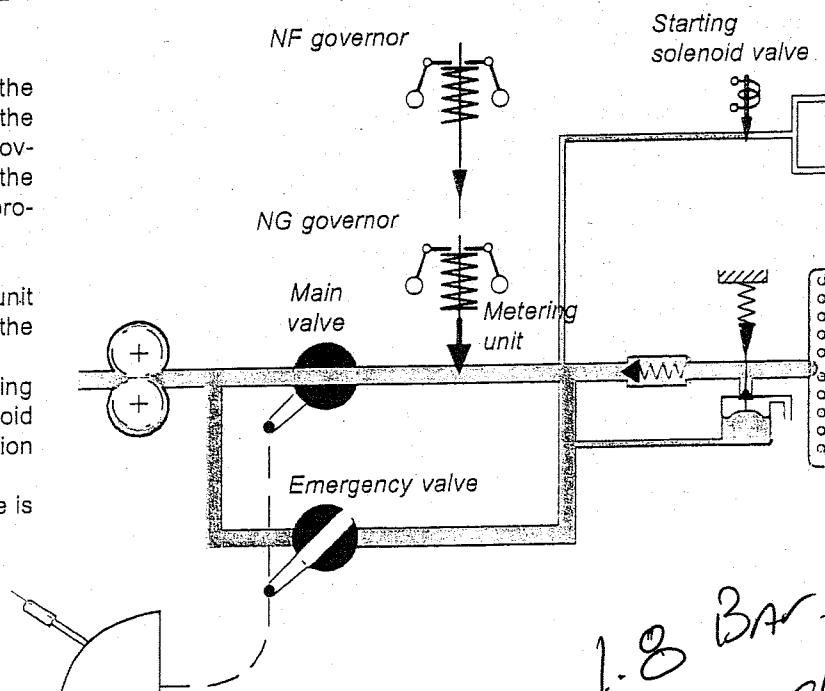
With the fuel flow control lever in the "FLIGHT" position (forward detent), the main flow valve is fully open and the governing system monitors the fuel flow (the engine accelerates as the valve is progressively opened).

The NG governor:

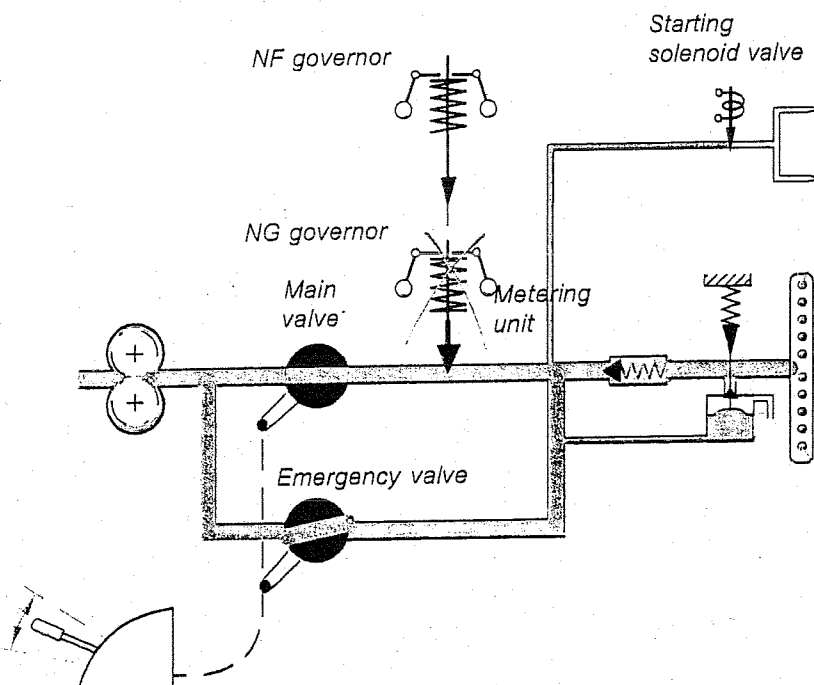
- controls the setting of the metering unit based on the orders it receives from the free turbine (NF) governor.

- monitors transient speeds by adjusting the fuel flow during acceleration to avoid engine surging and during deceleration to prevent engine flameout.

NOTE that the starting solenoid valve is closed and the bleed valve open.

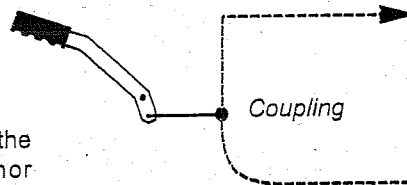


*1.8 Bars
To open check
valve - START.*

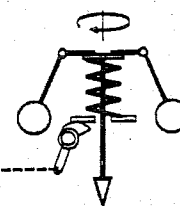


When the fuel control lever is moved beyond the "FLIGHT" detent, the emergency valve progressively opens to supply the engine if the governing system has failed and closed the metering unit. The fuel then flows directly through the emergency valve whose opening the pilot adjusts as a function of the collective pitch. The pilot must now CLOSELY MONITOR THE OPERATING PARAMETERS (NG - T4) since the governing system no longer provides any protection.

Collective pitch lever



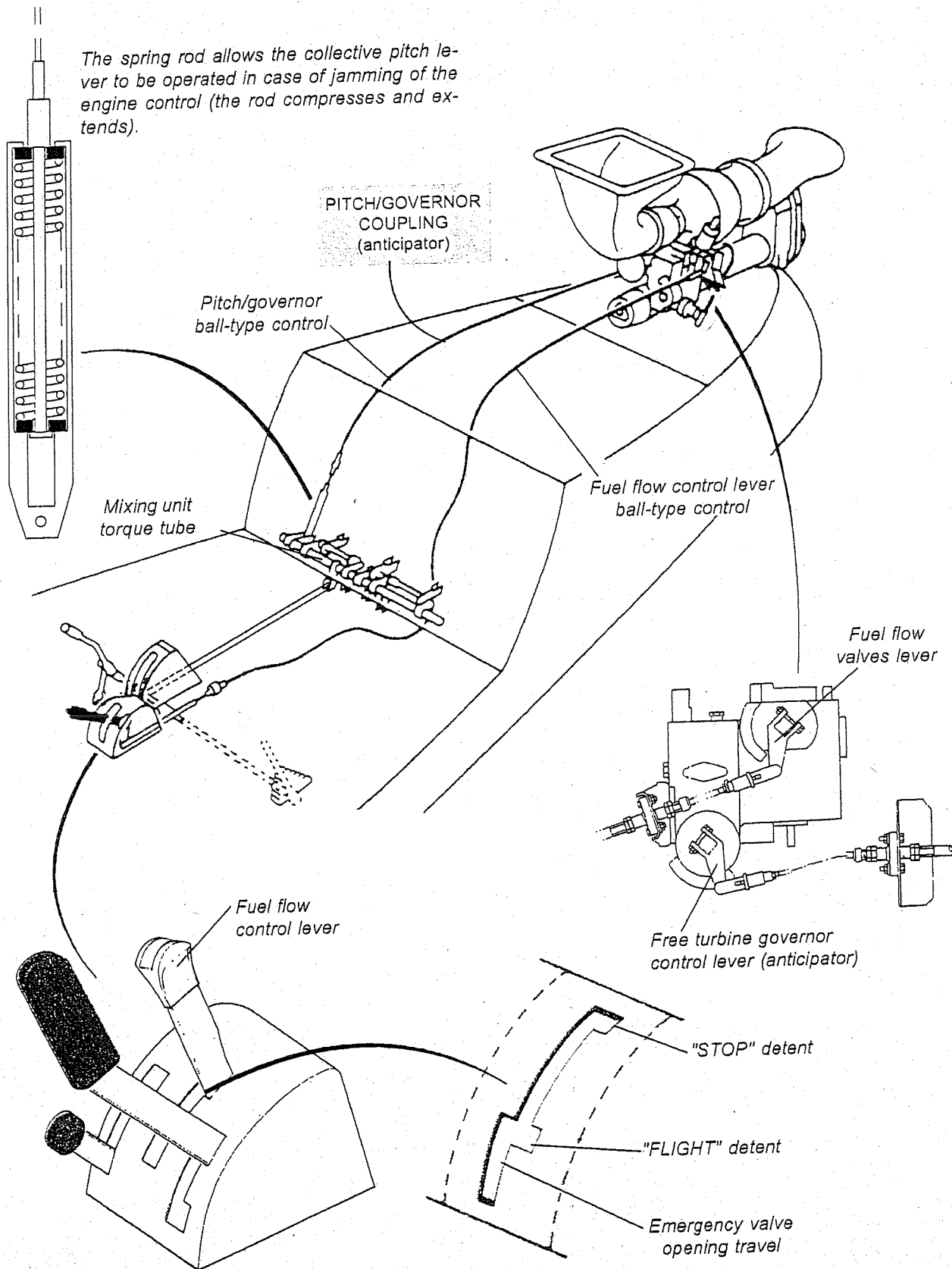
NF governor



THE GOVERNING SYSTEM acts on the free turbine governor. The governor spring setting automatically varies with the collective pitch lever position.



14.4.3. ENGINE CONTROL LINKAGE COMPONENTS AND THEIR LOCATION





14.5- ENGINE POWER MONITORING

14.5.1. GENERAL

The power parameters are :

The GAS GENERATOR rpm (NG).

The power produced by the engine varies with NG, which directly depends on the quantity of fuel ignited (engine consumption). NG increases with increasing fuel consumption.

The GAS TEMPERATURE (T4) at the free turbine inlet. This temperature depends mainly on the quantity of fuel ignited.

The ENGINE TORQUE (Cm)

The torque transmitted to the rotors by the free turbine.

The engine torque represents the power
ABSORBED BY THE ROTORS
(power varies with the collective pitch).

Now the power absorbed by rotors = $Cm \times \omega$

As ω (rotor rpm) = constant, the power absorbed by the rotors is proportional to the engine torque.

By monitoring these 3 parameters, the pilot knows the engine is operating correctly and...

... MOST IMPORTANT OF ALL, HE CAN COMPLY WITH THE SPECIFIED LIMITATIONS.

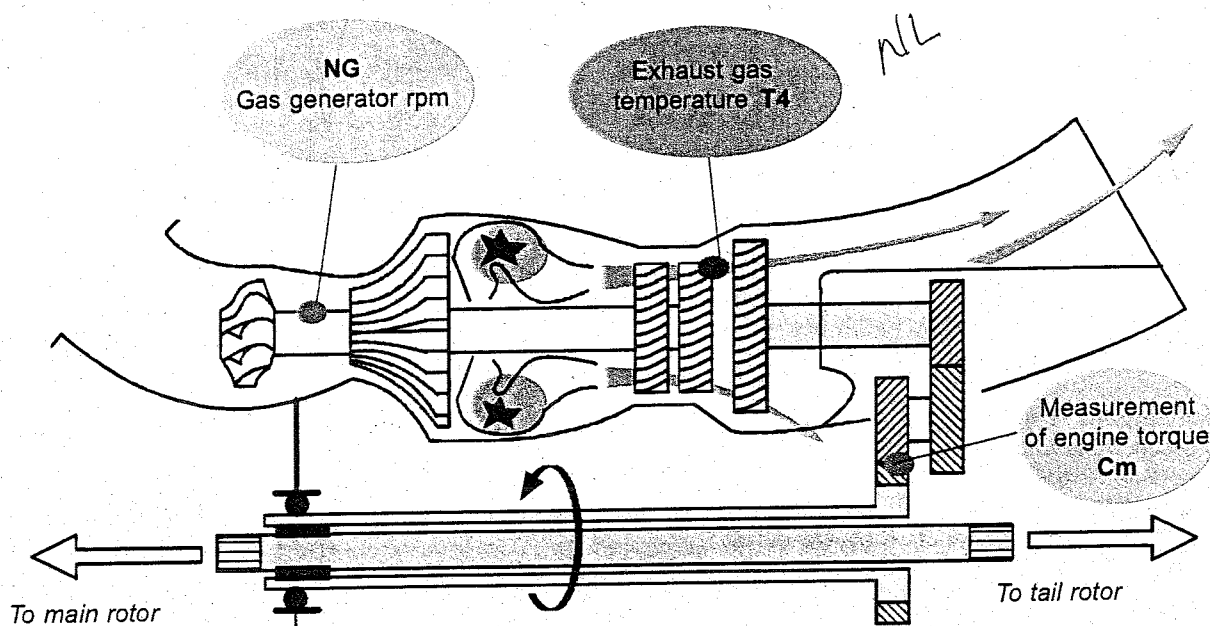
A few words on power limitations:

Power generates mechanical stresses (e.g. centrifugal forces on the turbine blades, specific bearing pressure on gear teeth, loads on bearings, etc.) and thermal stresses (notably in the combustion chamber and turbines). When these stresses exceed certain limits, they ARE DETRIMENTAL TO THE MATERIALS, reducing their fatigue strength; repeatedly exceeding these limits over a period of time creates a risk of rupture. These thresholds are determined by the manufacturers.

They form LIMITATIONS, i.e.:

- **NG and T4 limitations** to protect the engine.
- **Torque (Cm) limitations** to protect the MGB.

These limitations are specified in the Flight Manual.



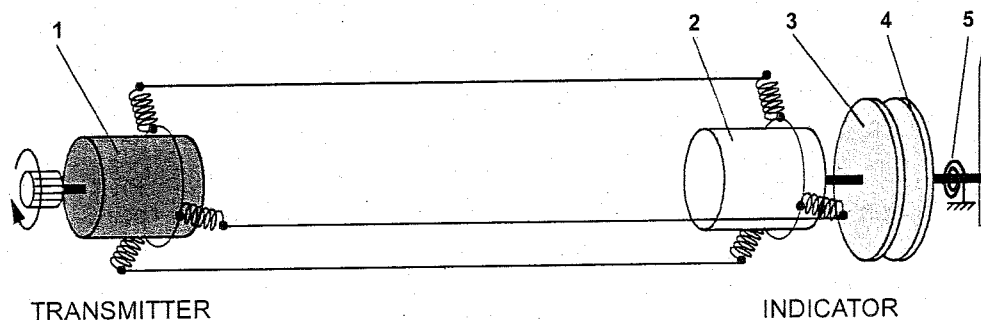


14.5.2. GAS GENERATOR SPEED (NG) MONITORING

(1) NG measuring system on engine versions B, B1 and BA

This measuring system is self-contained. Its transmitter is a three-phase alternator (1) (or rate generator), whose rotor is driven by the gas generator. The alternator outputs a current with a frequency proportional to NG. This current is fed to the receiver (indicator), i.e. a synchronous motor whose rotor (2) rotates at the same speed as the alternator and drives a magnet (3).

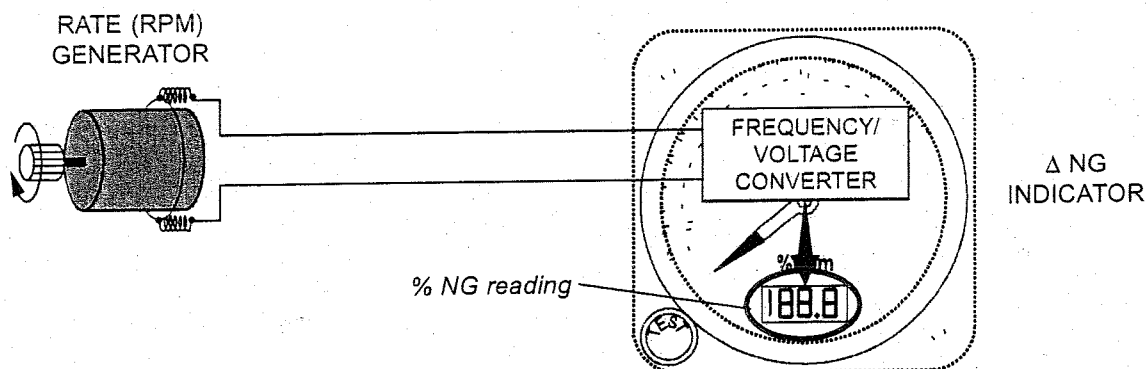
The rotating magnet induces (eddy currents) a torque on an aluminium disc (4) integral with the indicator pointer. The disc drive torque, balanced by a spiral spring (5), is proportional to the magnet rpm, therefore to NG.



(2) NG measuring system on engine version B2

The engine has its own independent measuring system consisting of a 2-pole rate generator/transmitter driven by the engine accessory gearbox. The generator's frequency output is transformed by a converter inside the

indicator into a voltage that is proportional to the engine rpm and is displayed as percent Ng on the digital readout (100% Ng = 51,800 rpm).



14.5.3. EXHAUST GAS TEMPERATURE (T4) MONITORING

The gas temperature is measured at the free turbine inlet by chromel-alumel thermocouples which output a voltage proportional to the temperature being measured. Three such thermocouples, mutually indexed at 120°, are located in the exhaust gas duct. They are parallel-mounted so that the millivoltmeter reads the highest voltage and hence the highest temperature. No adjustment is needed to match the thermocouples with the indicator.

